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Understanding the micromechanics of ductile steel fibre - polymer composites

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INTRODUCTION

A common limitation of structural fibre-reinforced polymers is their low toughness and ductility. This is due to the intrinsic brittleness of conventional fibres. In the present work we use a new type of fibres – annealed stainless steel fibres that combine a high stiffness and a high strain-to-failure.

To fully exploit the unique potential of steel fibres, the micromechanical behaviour must be well understood.

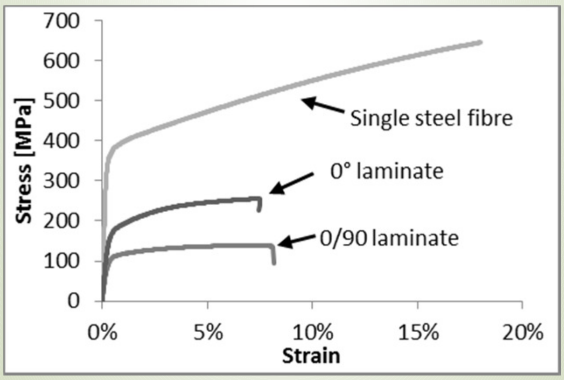
OBJECTIVE

In contrast to typical fibres such as carbon and glass fibres, which behave linear elastic, ductile steel fibres possess a highly non-linear stress-strain behaviour.

This research employs simple modelling to separate the non-linear behaviour of the ductile steel fibres and the matrix from the damage occurring in a composite laminate under static tensile loading. The modelling is used as a tool to understand how the composite behaviour is affected by exchanging the brittle fibres by ductile fibres.

TENSILE BEHAVIOUR OF STEEL FIBRE COMPOSITES

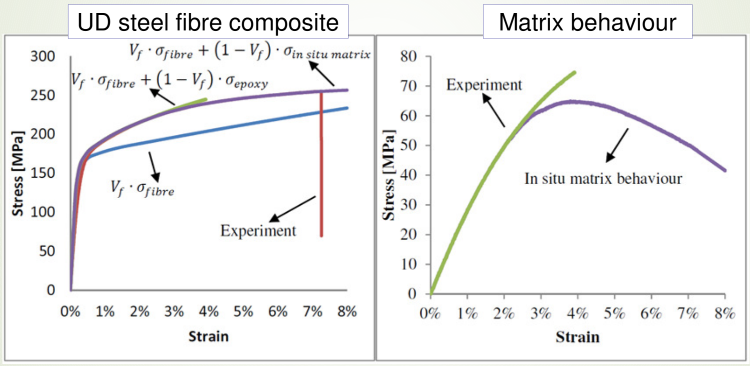
Steel fibre composites have a high stiffness: only ± 20% less than the stiffness of carbon fibre composites and 2.5 times higher than the stiffness of glass fibre composites.



The measured strain-to-failure is only around 7%, which implies that the potential of the steel fibres (± 20%) is not yet fully exploited. Nevertheless, the strain-to-failure is already ±3.5 times higher than carbon fibre composites and ±3 times higher than glass fibre composites.

IN-SITU BEHAVIOUR OF THE MATRIX

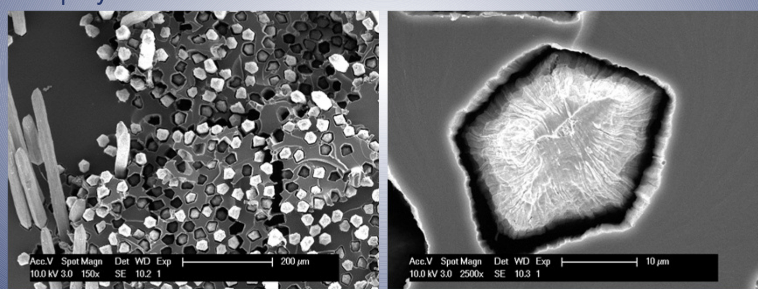
Simple micromechanical modelling is used to understand the elasto-plastic behaviour of steel fibre composites. First we assume that only the longitudinal fibres carry the load (blue). Then the stress-strain curve of the matrix is added (green).



By fitting the modelled stress-strain curve to the experimentally measured one, the in situ behaviour of the matrix can be calculated (purple). This helps us to understand when damage initiates and how it affects the tensile behaviour.

FRACTURE SURFACE

The fracture surface reveals that all fibres debond from the matrix and fail in a ductile manner. The fibre/matrix interphase thus plays a vital role in the failure behaviour.



CONCLUSION

Ductile steel fibres deliver composites with a high strain-to-failure. The stress-strain diagram of these composites can be modelled using simple micromechanical equations. Further research is needed to find the most suitable matrix and fibre/matrix interphase to exploit the full potential of the steel fibres.

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